

# PATENT SPECIFICATION

DRAWINGS ATTACHED

1.045.002

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## COMPLETE SPECIFICATION

### Improvements in or relating to A.C. Line Regulators

We, STANDARD TELEPHONES AND CABLES LIMITED, a British Company, of Connaught House, 63 Aldwych, London, W.C.2., England, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to voltage regulators supplied from an unregulated A.C. source. The regulated output may for example be A.C., or it may be rectified and smoothed D.C.

It has previously been known to use regulators incorporating magnetic amplifiers, moving brushes, moving coils or vacuum tubes. The magnetic amplifier types are bulky, inefficient, slow in response and either introduce distortion or require large filters which are inefficient and slow in response. The moving brush and moving coil types are also bulky and slow in response and present maintenance problems. Vacuum tube types are inefficient, limited in power handling capacity and utilise consumable items. The regulator according to the present invention utilises static devices, is fast in response, efficient, relatively small, requires little maintenance and is flexible in application.

According to this invention a voltage regulator supplied from an A.C. source comprises means for chopping the A.C. input into pulses at a frequency which is high with respect to the frequency of the input, a comparator for comparing the output voltage with a reference voltage and generating control signals, and a controller under the control of the control signals which controls the ratio of the periods of time for which the chopper is turned on and off such that an increase in the output voltage at the load causes a decrease in the pulse width or a decrease in frequency or both.

[Pric

Reference will now be made to the accompanying drawings in which:

Figure 1 is a block diagram of a regulator according to this invention providing an A.C. output,

Figure 2, Figure 3 and Figure 4 are circuits partly shown in block form, which may be used in the invention, and

Figure 5 is a block diagram showing an additional facility which may be provided, and to the drawings lodged herewith in which

Figures 6 is a block diagram of a single phase voltage regulator in accordance with this invention, giving a D.C. output,

Figure 7 is a block diagram of a three phase voltage regulator developed from the single phase regulator of Figure 6,

Figure 8 is a diagram showing typical waveforms appearing at various points of the regulator of Figure 6,

Figures 9a, 9b, 10a, 10b and 10c are circuits of typical semiconductor chopper switches that may be used in the invention. Referring to Figure 1 the unregulated sinusoidal input at the fundamental frequency, represented by waveform 1, is applied to chopper 2 wherein it is chopped into a succession of pulses as represented by waveform 3. These pulses, which are thus amplitude modulated at the fundamental frequency, are applied to a low pass filter 4 which blocks all but the fundamental frequency which is applied to the load as represented by waveforms 5. A portion of the output 5 is applied to comparator 6 to which a reference voltage from 8 is also applied. The voltage resulting from the comparison is applied to controller 7 which produces pairs of signals at a frequency much greater than the fundamental, say 10 times, the spacing between the first and second signal of a pair determining the width of the pulse produced by the regulator

2. If it is desired to change the voltage level, for example to obtain a higher voltage at the load than at the input, a transformer may be used at the input at 10 or prior to the load at 9.

It should be noted that the filter 4 requires only to block frequencies at the chopper repetition rate and higher and hence is small, efficient and fast in response compared with a filter required to block lower frequencies such as lower harmonics of the fundamental.

Figure 2 shows one circuit, in which the chopper is shown in detail, which can be used to achieve a regulator according to this invention. TR1 and TR2 are transistors connected in parallel in such a way that TR1 can conduct when input terminal 11 is negative with respect to input terminal 12, and TR2 can conduct when 11 is positive with respect to 12. D1 and D2 are blocking diodes to prevent reverse current passing through TR1 and TR2. Inductor L1 and capacitor C1 form a simple low pass filter 4 and as such have a cut-off frequency lower than the chopper repetition frequency but higher than the fundamental. The output voltage is sensed at terminals 13 and 14, is compared with a reference voltage in 6 and the comparator output is applied to controller 7 which in turn applies pulses to base electrodes 16 and 17 of TR1 and TR2. Details of the comparator and controller are not shown, but may consist of a transformer and rectifier to produce a D.C. signal proportional to the output voltage between 13 and 14, a zener diode to provide a reference voltage, and a D.C. amplifier to amplify the difference between the D.C. signal and the reference. This difference may then be applied to a trigger circuit in such a manner as to determine the width of its square pulse output. This trigger circuit may for example be a Schmitt trigger which is separately excited to produce pulses at the desired chopper regulator repetition rate. This square wave output can thus be applied between the base and emitter electrodes of TR1 and TR2 causing them to switch on and off as desired.

Figure 3 shows a circuit performing a similar function but employing silicon controlled rectifiers SCR1 and SCR2 which can be turned ON and OFF by pulses of suitable polarity applied to the gate electrodes. Such pulses could be provided for example, by differentiating the square wave output of the Schmitt trigger described in relation to Figure 2, thus producing pulses at the start and finish of each square wave.

Figure 4 shows a further circuit performing a similar function employing silicon controlled rectifiers SCR3 and SCR4 which can be turned ON but not OFF by pulses of suitable polarity at the gate electrodes. In this case during one half cycle of the applied alternating current SCR3 is turned ON by the first

of a pair of pulses applied to its gate. The second pulse of the pair is applied to the gate of SCR5 causing it to conduct: the charge acquired by capacitor C2 through the intermediary of auto transformer T1 and rectifier D3 then causes a current to flow in a reverse direction through SCR3 for a short period until it ceases to conduct and returns to the blocking state in readiness for its next conduction pulse. Similarly during the other half cycle of the applied alternating current SCR4 is turned ON by the first of a pair of pulses and is caused to return to the blocking state at the end of each conduction period by means of SCR6, C3, D4 and T2.

Distortion and undesired voltage transients may occur at the end of each copper pulse if the impedance presented to the chopper is other than resistive. To overcome this a shunt path may be interposed between the chopper and the filter as shown in Figure 5. In this diagram 2 is the chopper and 4 is a filter as previously described. The shunt chopper 19 may comprise a chopper similar to 2 but so arranged that each is conducting only when the other is non-conducting. In this way the pulses are transmitted to the filter 4 as previously described when 2 is conducting, and a low impedance is presented by 19 to the filter 4 and load thus maintaining continuity of current flow and avoiding transient voltages induced when 2 is non-conducting.

Fig. 10a shows a circuit performing the dual function of both series chopper and shunt chopper employing silicon controlled rectifiers in which silicon controlled rectifiers 33 and 34 form the series switch and silicon controlled rectifiers 35 and 36 form the shunt switch and capacitors 38 and 39 and choke 37 form a commutating circuit for the silicon controlled rectifiers.

The series switch is switched on by applying positive pulses to the triggers of silicon controlled rectifier 33 and 34 and commutated off by switching the shunt switch on by applying positive pulses to silicon controlled rectifiers 35 and 36.

Figure 10c shows an additional facility that may be added to the circuit in Fig. 10a to limit excessive voltage transients that may be generated within the commutating circuit and to feed back to the incoming power lines energy that may otherwise be trapped or dissipated and lost within the commutating circuit.

Components 58 to 64 form the basic series shunt switch arrangement shown in Fig. 10a.

When the input terminal 50 is positive with respect to terminal 49 silicon controlled rectifiers 54 and 55 are triggered to the conducting state so that when the series switch containing silicon controlled rectifiers 58 and 59 is conducting terminal 51 can become no more positive with respect to terminal 50 than the voltage at tap 52 on auto-trans-

former 65 so that the peak forward blocking voltage applied across the shunt switch containing silicon controlled rectifiers 60 and 61 is no greater than the line voltage between terminals 49 and 50 plus twice the voltage between terminal 50 and tap 52. Also energy stored in choke 62 in the form of current may flow via silicon controlled rectifiers 58, 54 and transformer 65 back into the incoming line.

Similarly if the shunt switch is conducting the forward voltage across the series switch is limited or if the terminal 50 is negative with respect to the terminal 49 then silicon controlled rectifiers 56 and 57 are caused to conduct.

In the arrangement of Figure 6, single phase A.C. voltage is fed from the A.C. power source 1 to the controlled A.C. chopper switch 2 and transformer 20. The transformer 20 transforms the chopper A.C. voltage to the desired voltage and current levels where it is then rectified by the bridge rectifier 21 and filtered by low pass filter 22. The resulting D.C. output voltage is fed to a comparator 6 where it is compared with a D.C. reference voltage 8. If the output voltage is less than the reference voltage a signal is transferred to the control circuit 7 and through to the chopper switch 2 causing it to close. If the output voltage is greater than the reference voltage then no signal is transferred to 7 so that the chopper switch 2 remains open. Thus the chopper switch remains closed until the output voltage builds up to the desired reference level and thereafter alternates from the closed state to the open state maintaining the output voltage close to the desired reference voltage. Typically the periods of closure of the chopper switch are only a small fraction of the period of the A.C. source voltage waveform and the frequency of closure an order of magnitude greater than the frequency of the A.C. source voltage waveform. A typical output waveform from the chopper switch is shown in Figure 8 together with the resulting ripple waveform on the D.C. output. Thus the filter is required to store less energy for shorter periods of time than is required of a filter used in the normal uncontrolled or a phase controlled bridge rectifier power supply so that a smaller and more efficient filter may be designed to keep the output ripple to within a given limit. Also since less energy is stored within the filter components, particularly the inductive components, voltage surges caused by the release of stored energy from the inductive components on the removal of load are reduced. Since the applied A.C. power source may be connected or disconnected at any instant a more rapid response to source voltage changes and load changes may be achieved than is possible with magnetic amplifiers of phase controlled switches.

Referring to Figure 7, a three phase A.C.

supply voltage is fed to terminals 23, 24, 25 and then through chopper switches 2, 2', 2'' to three phase transformer 27. The secondary windings of transformer 27 feed the three phase rectifier 28 and output filter 29. The D.C. output voltage is fed to the comparator 6 and compared with the D.C. reference 8. If the D.C. output is less than the reference voltage, then a signal is fed to the control circuit 7 and through to chopper switches 2, 2' and 2'' causing them to close. If the D.C. output is greater than the reference voltage then no signal is fed to the control circuit 7 and through to chopper switches 2, 2' and 2'' so that they remain open.

The mode of operation of the chopper switches in the three phase circuit is similar to the single phase case previously described. The three phase circuit offers a further advantage that there is always a potential available at any instant between two or the supply phases that may supply energy to the system; whereas in the single phase circuit the supply potential reduces to zero each half cycle so that there is need to store additional energy within the filter system to supply the load near the supply voltage zeros. Thus less filtering is required in the three phase circuit than in the single phase circuit.

Typical circuit arrangements that may be used for single and three phase transistor chopper switches are shown in Figure 9(a) and 9(b) respectively. In Figure 9(a) transistor 30 carries the A.C. current over both positive and negative half cycles by means of the diode bridge arrangement. In Figure 9(b) transistor 31 controls the current in one direction while the diode 32 carries the current in the reverse direction.

Typical circuit arrangements that may be used for single and three phase or silicon controlled rectifier chopper switches are shown in Figure 10(a) and 10(b) respectively. Figure 10(a) has already been described.

In Figure 10(b) silicon controlled rectifier 40 and the commutating circuit containing silicon controlled rectifier 41, inductor 42 and capacitors 43 and 44 control the flow of current in one direction while diode 45 carries the flow of current in the reverse direction.

#### WHAT WE CLAIM IS:—

1. A voltage regulator supplied from an A.C. source comprising means for chopping the A.C. input into pulses at a frequency which is high with respect to the frequency of the input, a comparator for comparing the output voltage with a reference voltage and generating control signals, and a controller under the control of the control signals which controls the ratio of the periods of time for which the chopper is turned on and turned off such that an increase in the output voltage causes a decrease in the pulse width, a decrease in frequency, or both.

2. A voltage regulator as claimed in claim 1 in which the output is A.C., and a filter is interposed between the chopper and the output, the filter having a cut-off frequency lower than the chopper frequency but higher than the A.C. input frequency. 5
3. A voltage regulator as claimed in claim 2 in which the A.C. output is rectified and compared with a reference D.C. voltage. 10
4. A voltage regulator as claimed in claim 1 in which the output from the chopper is rectified and smoothed, and the D.C. output voltage is the voltage that is compared with the reference voltage. 15
5. A voltage regulator substantially as described and as shown in Figure 1, or Figure 1 as modified by Figure 5, of the drawings. 20
6. A voltage regulator substantially as described and as shown in Figures 6 or 7 of the accompanying drawings. 25
7. A voltage regulator substantially as described in which the chopper includes a silicon controlled rectifier shunt-series switch arrangement as shown in Figure 10(a) of the accompanying drawings whereby forward voltages spikes and feedback are limited and commutating energy is recovered. 30
8. A voltage regulator substantially as described in which the chopper includes a silicon controlled rectifier shunt-series switch arrangement as shown in Figure 10(c) of the accompanying drawings whereby forward voltage spikes and feedback are limited and commutating energy is recovered.

S. R. CAPSEY,  
Chartered Patent Agent,  
For the Applicants.

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COMPLETE SPECIFICATION

5 SHEETS

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the Original on a reduced scale  
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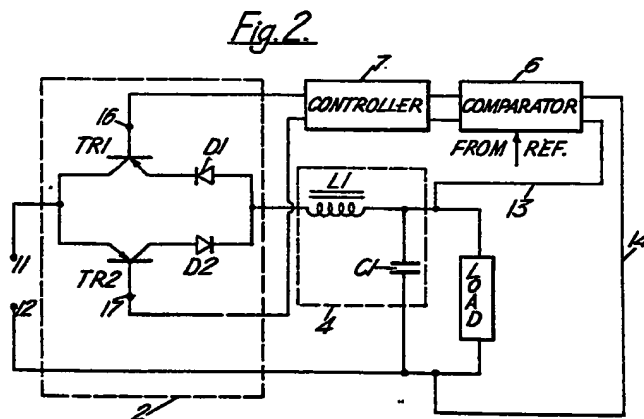
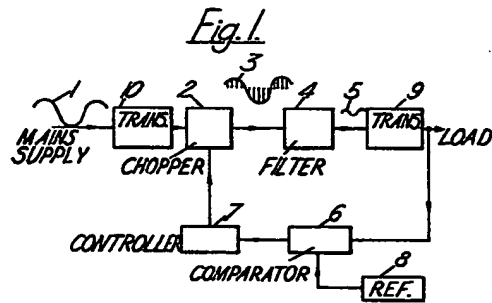


Fig. 3

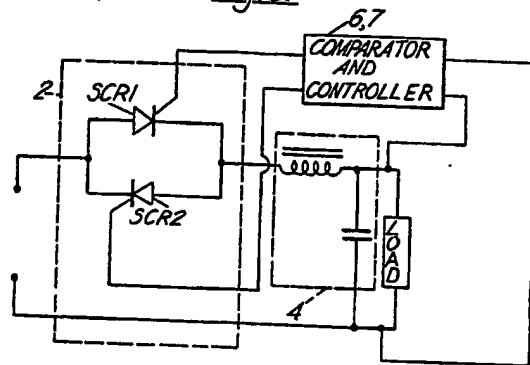


Fig. 4

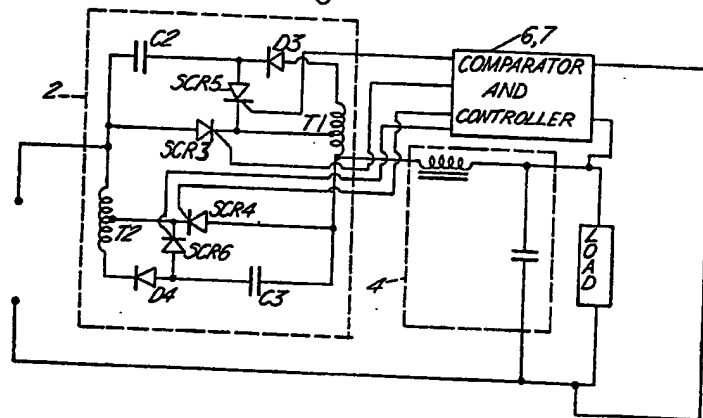
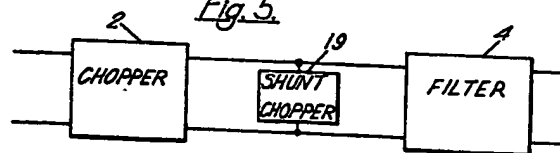
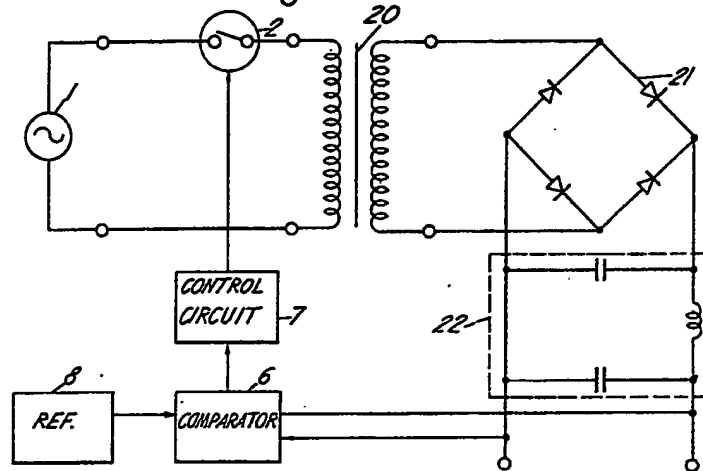


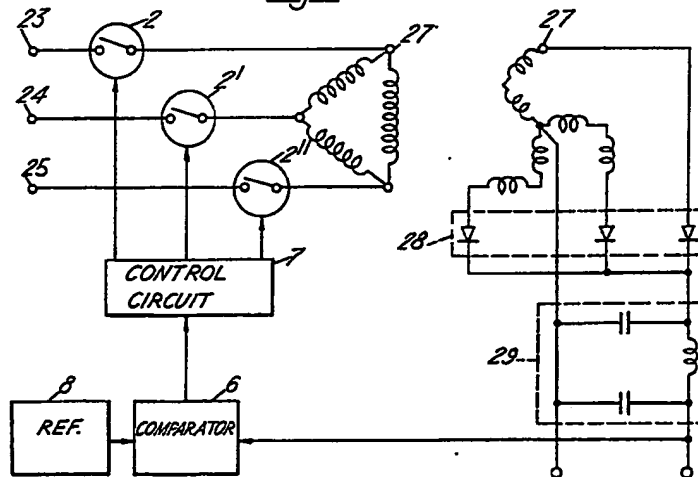
Fig. 5



*Fig. 6.*



*Fig. 7.*



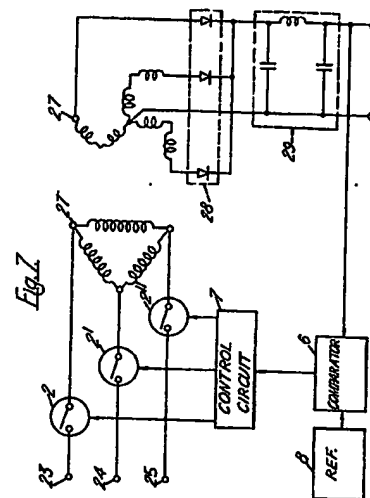
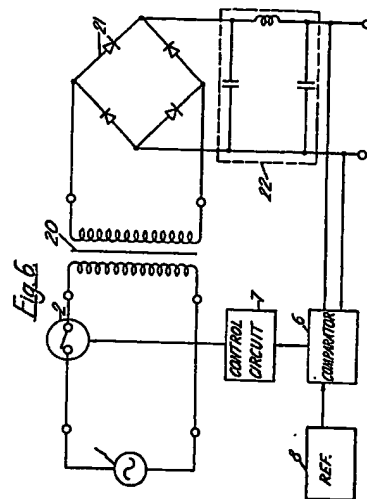
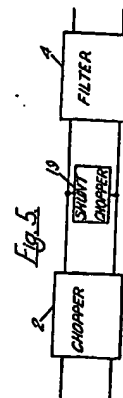
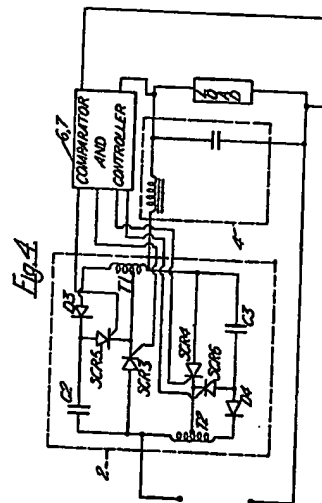
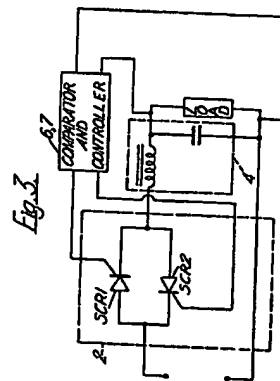


Fig. 9a.

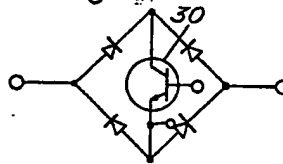


Fig. 9b.

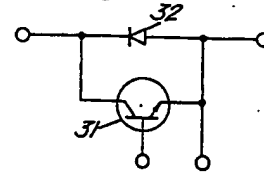


Fig. 10a.

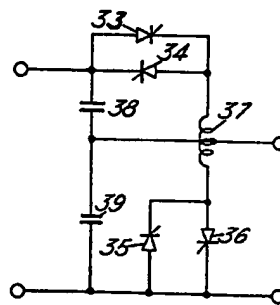


Fig. 10b.

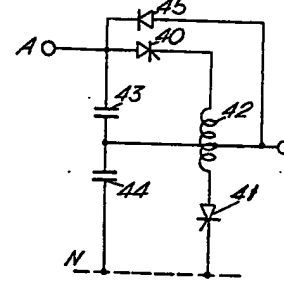
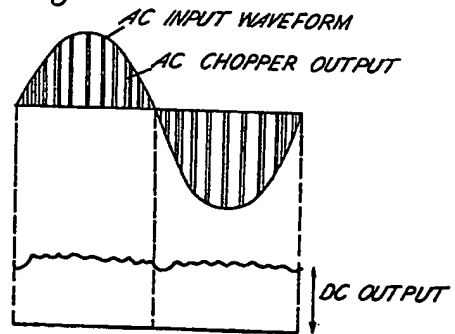


Fig. 8.

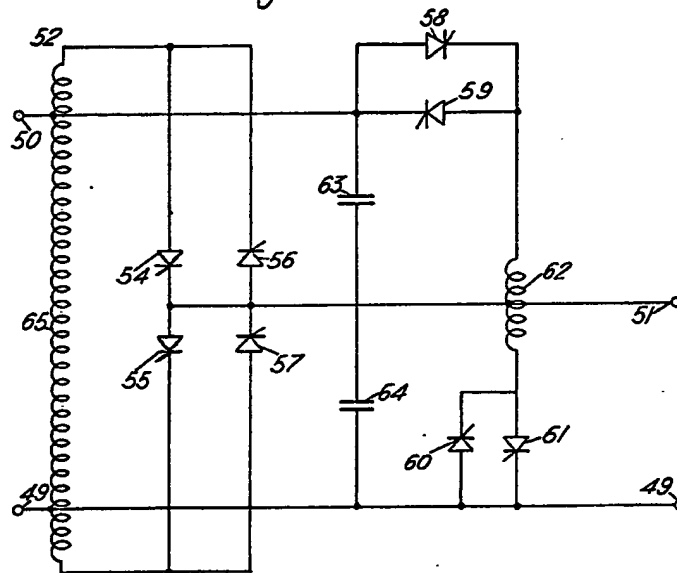


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5 SHEETS

*This drawing is a reproduction of  
the Original on a reduced scale  
Sheets 4 & 5*

*Fig. 10c.*



PUT

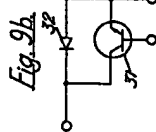
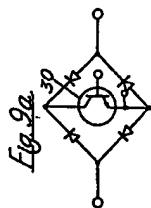


Fig. 10a.

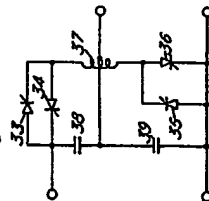


Fig. 10b.

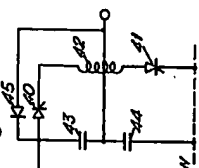


Fig. 8.

